2012

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Class A Lighting

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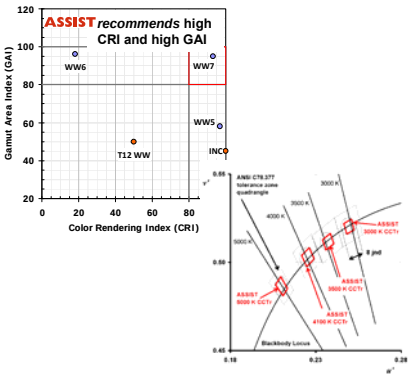
Introduction

- **Color rendering** and the **color of illumination** are two key factors that support architectural lighting (e.g. retail lighting).
- However, presently accepted metrics used to describe color properties (CRI and CCT) often are not perfectly predictive of people's assessments of illumination from a light source.

Amerlux

ASSIST recommends: Retail Lighting

- Guide to Light and Color in Retail Merchandising
- Recommendations for Specifying Color Properties of Light Sources for Retail Merchandising

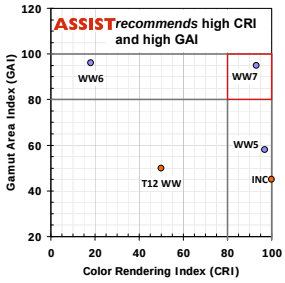


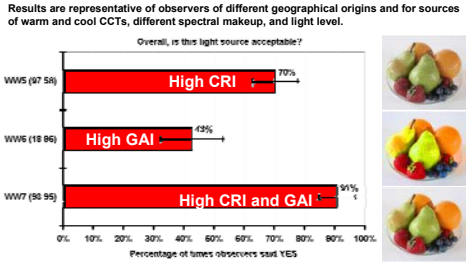
www.lrc.rpi.edu/programs/solidstate/assist/recommends.asp

Color Rendering of Illumination

Color rendering: CRI+GAI approach

- No single metric can characterize color rendering, period.
  - Good color rendering by a light source depends on providing an optimum amount of color saturation (but without distortion; e.g., objects look like under daylight.)
  - Two-metric strategy with well established CRI plus GAI as adjunct is practical, predictive, and validated by human factors studies.



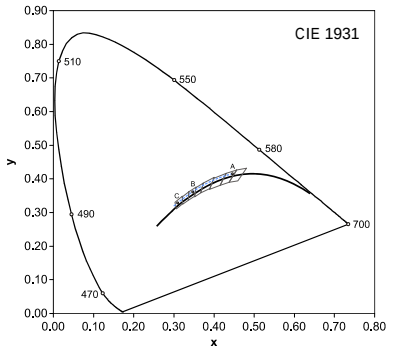


•Rea, M.S. and J.P. Freyssinier-Nova. 2008. Color rendering: A tale of two metrics. *Color Research and Application* 33(3): 192-202.
•Rea, M.S., and J.P. Freyssinier. 2010. Color rendering: Beyond pride and prejudice." *Color Research and Application* 35 (6): 401-409.

Color Appearance of Illumination

Light source color specification

- Correlated color temperature is the most used metric to specify light source color appearance
  - Based on light source chromaticity

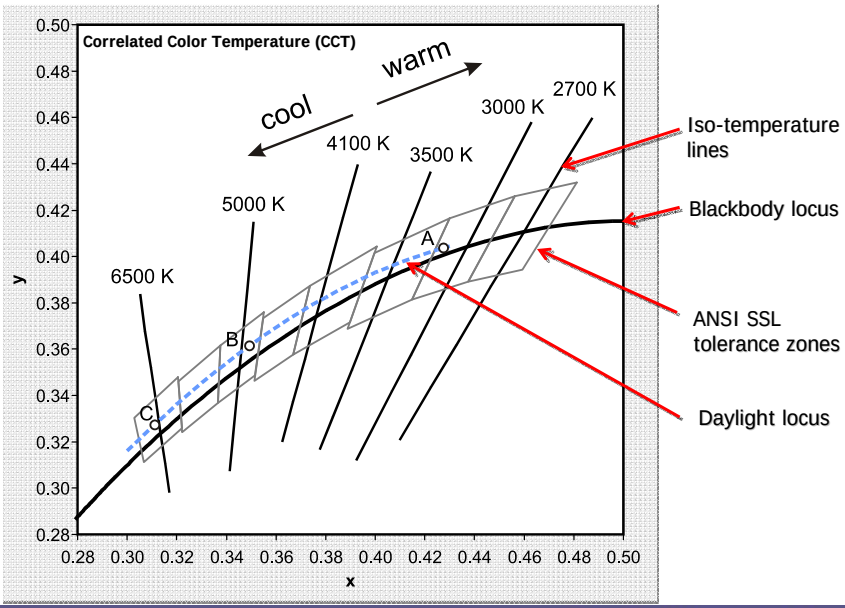


NLPIP

Table 1. Most useful light source color characteristics.

Characteristic	Average Usefulness Rating	Standard Deviation	Number of Responses
Color Rendering Index (CRI)	3.5	0.7	237
Correlated Color Temperature (CCT)	3.2	1.0	233
Color Stability	3.2	1.0	232
Lamp Type	3.1	1.0	235
Color Consistency	3.1	1.0	228
Spectral Power Distribution (SPD)	2.4	1.2	226
Full-Spectrum Index (FSI)	2.0	1.3	204
Brand Name	1.9	1.2	226
Gamut Area	1.5	1.2	189

(Rating Key: 0 = Not useful; 4 = Very useful)

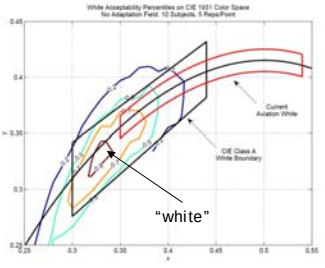


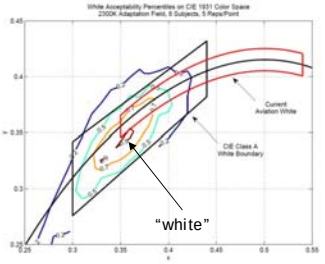
Goal

- To conduct a laboratory psychophysical experiment to investigate the subjective target chromaticity of white illumination from lamps of different CCTs.

Past research: Aperture mode

- Previous research has been conducted for *aperture* mode viewing (very small field of view, for signaling purposes).
- Past research also differs in background conditions and luminance, thus the "white points" in the literature are not applicable to illuminant mode viewing.

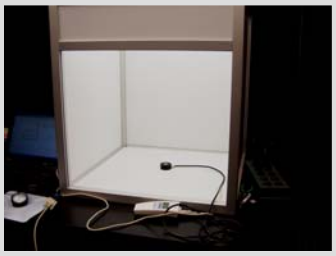




Bierman A, Skinner NP, Narendran N. 2009. Re-Evaluating the Chromaticity Boundaries for Aviation White Light. Illuminating Engineering Society Aviation Lighting Committee Conference.

Experimental approach

- Illuminant mode: Viewing box with multiple light sources
  - Computer controlled to produce specific chromaticities and light levels
  - Active feedback provides temporal stability
  - Horizontal illuminance: 30 fc



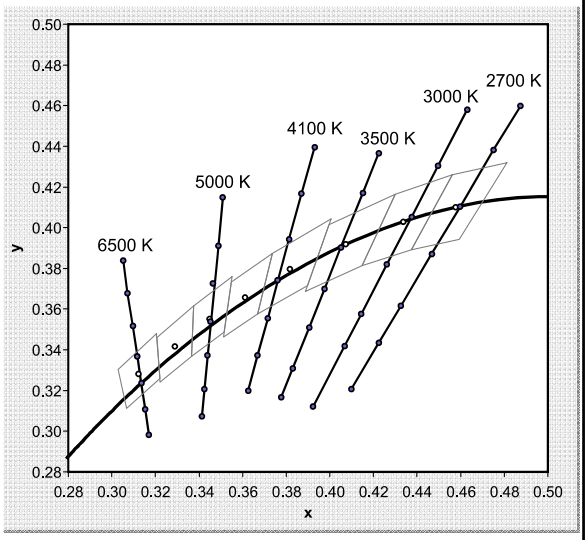
Experimental approach

- Six correlated color temperatures 2700-6500 K
- Seven chromaticities along each CCT line
- Subjective responses to four questions
  - Immediately after seeing the light source
    - Hue of light source: Green/yellow or purple/violet (hue choice)
    - Percent of hue relative to a pure white (hue %)
  - After 45 seconds adaptation
    - Hue of light source: Green/yellow or purple/violet (hue choice)
    - Percent of hue relative to a pure white (hue %)
- One viewing distance, 12-in from the opening of the box

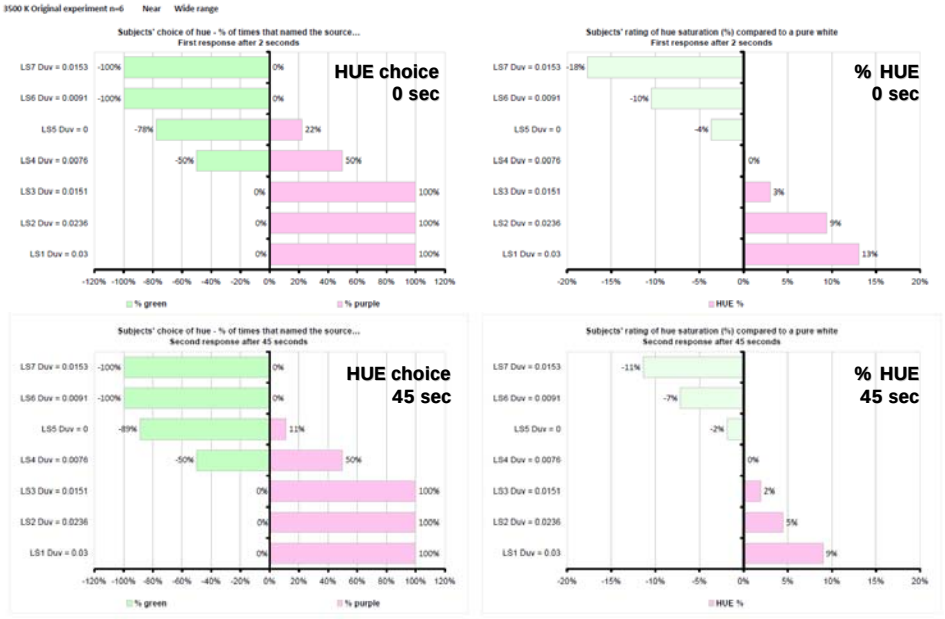
Experimental approach

Questions:
- Hue choice
- Hue percent tint

Immediately and after 45 s adaptation

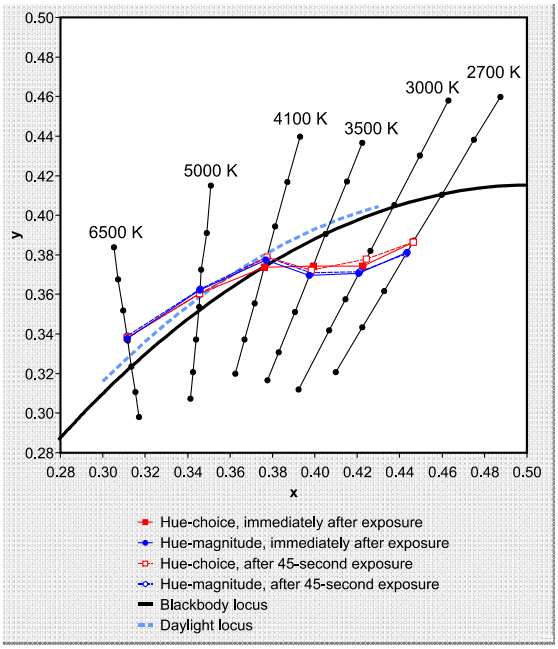


Results

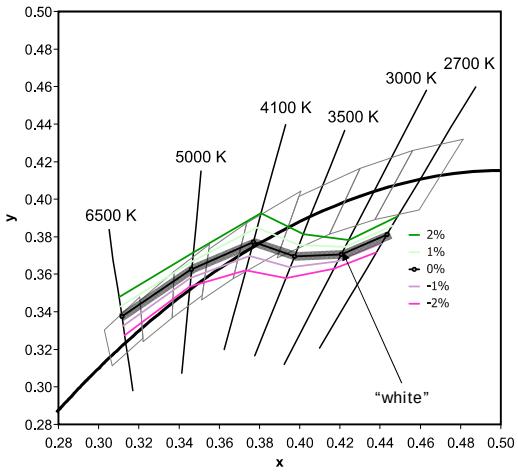


Results

- For each CCT, a "white" point (i.e., a chromaticity of minimum tint) can be estimated for each of the four questions
- The four "white points" are close together for each CCT
  - White is white; does not change with time
- White points for CCT<4000 K are below the blackbody locus, and above the blackbody locus for CCT>4100 K



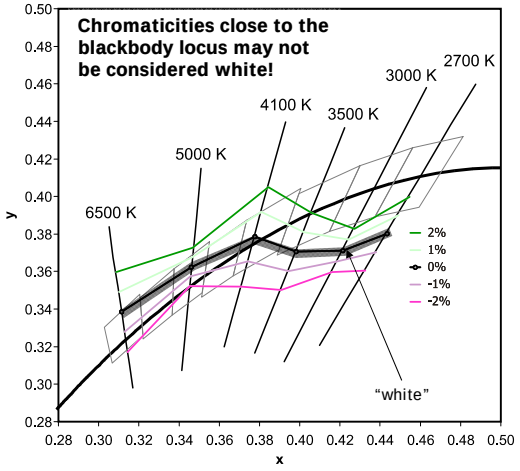
Iso-contours for judgments immediately following presentations *



* Rea, M.S. and J.P. Freyssinier. 2011. White lighting. In press with *Color Research and Application*. doi: 10.1002/col.20738

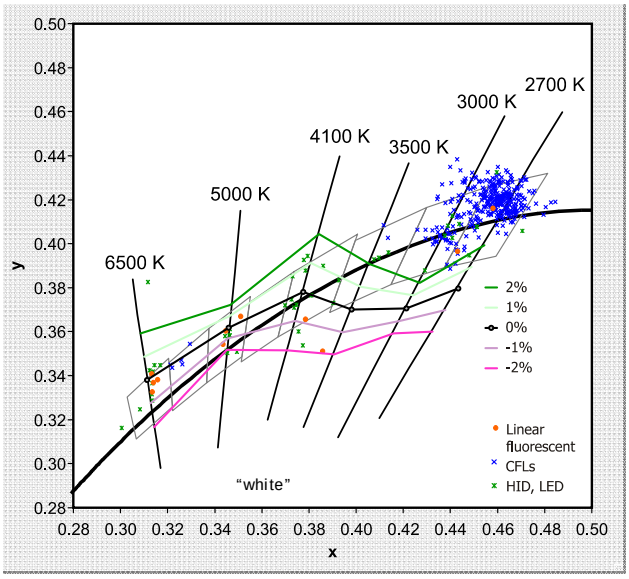
Iso-contours for judgments 45 sec after presentations*

- White points remain in the same place but the range -2% to +2% increases because of the chromatic adaptation that occurs over time
- Sources appear less saturated, i.e., with less tint



* Rea, M.S. and J.P. Freyssinier. 2011. White lighting. In press with *Color Research and Application*. doi: 10.1002/col.20738

Discussion



Implications for practice: Color appearance of the source

- Sources of the same CCT can have different hues/tints
- Change in CCT along the blackbody is not a dimension of whiteness
- Every CCT has a point of minimum tint
  - "White points" are not metamers

Implications for practice: Color appearance of the source

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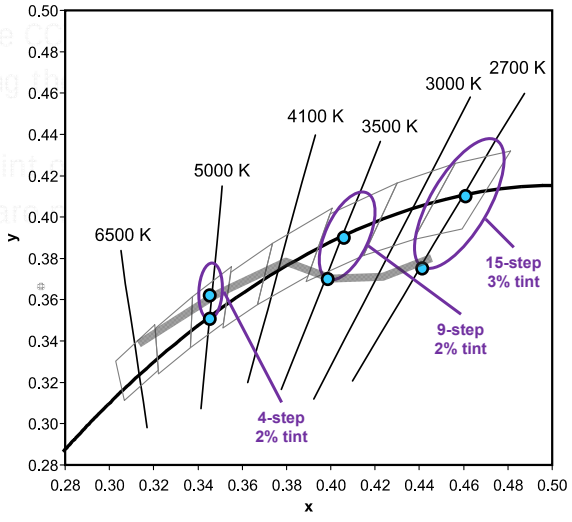


Implications for practice: Color appearance of the source

- Sources of the same CCT can have different hues/tints
- Change in CCT along the blackbody is not a dimension of whiteness
- Every CCT has a point of minimum tint
  - "White points" are not metamers
- Results can be applied in practice
  - People seem to prefer sources with less tint
- Light level matters
  - At higher light levels sources appear less tinted
  - At higher light levels, colors appear more saturated and the color of illumination closer to white

Implications for practice: Color rendering properties of the source

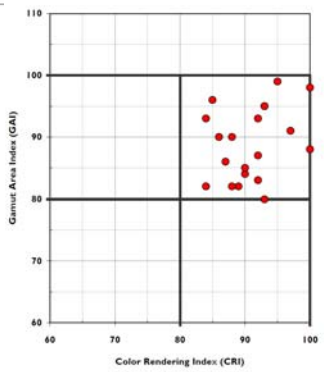
- CRI + GAI is practical and predictive
  - To ensure good color rendering, look for sources with CRI > 80 and 80 ≤ GAI ≤ 100
- Don't just believe the numbers
  - look at the color properties of these sources and compare to sources that are only high in CRI

Commercial Light Sources with 80≤ CRI and 80≤ GAI ≤100

Table 2. Examples of light sources that meet the criteria for CRI (≥80) and GAI (≥80 and ≤100). (The inclusion or mention of any specific brand or product in this table is for illustrative purposes only and does not constitute an endorsement by ASSIST or the Lighting Research Center.)

	Light source	Manufacturer	Product Model	CCT (K)	CRI	GAI
1	Xenon	OSRAM SYLVANIA	1000W	5853	97	91
2	PC-LED	Cree	XRE lamp	4154	84	82
3	PC-LED	Sharp	Zenigata	5097	95	99
4	RGB-LED	Various	Peak wavelengths of 465 nm, 545 nm, and 614 nm	4000	89	82
5	T5	General Electric	T5HO 850	4903	86	90
6	T5	General Electric	T5HO 865	5930	84	93
7	T8	General Electric	F32T8SPX50	4751	87	86
8	T8	General Electric	F15T8C50	4633	88	82
9	T8	Lumirsm	Lumichrome 1XX	5960	93	95
10	T8	Verilux	F32T8VLX	6369	85	96
11	T12	OSRAM SYLVANIA	Design50, 40W	4861	90	84
12	T12	General Electric	Sunshine F40C50	4944	92	87
13	T12	Duro-Test	Vita-Lite 5500	5159	88	90
14	T12	Lumirsm	Lumichrome 1XC	5207	92	93
15	T12	Philips	Colortone 75	6217	90	85
16	T12	Duro-Test	DAYLITE 65, 40W	6588	93	95
17	MH	Philips	CDM100W/4K	4075	93	80
18	MH	Philips	CDM150W/4K	4197	92	83
19	Daylight		CIE D50	5000	100	88
20	Daylight		CIE D65	6500	100	98

PC-LED: phosphor-converted white light-emitting diode
RGB-LED: red, green and blue LEDs mixed to create white light
T5: linear fluorescent, 16 mm diameter
T8: linear fluorescent, 25 mm diameter
T12: linear fluorescent, 38 mm diameter
MH: metal halide

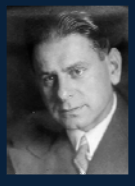


www.lrc.rpi.edu/programs/solidstate/assist/recommends/lightcolor.asp

Implications for practice: Class A light sources

- Class A light sources
  - have a chromaticity on or near the "white" line, and
  - provide white illumination with CRI > 80 and 80 ≤ GAI ≤ 100
- Hypothesis: Class A lamps will be more preferred than traditional lamps for general illumination

"The criterion of the scientific status of a theory is its falsifiability, or refutability, or testability."
– Karl Popper (1963)



Thank you!

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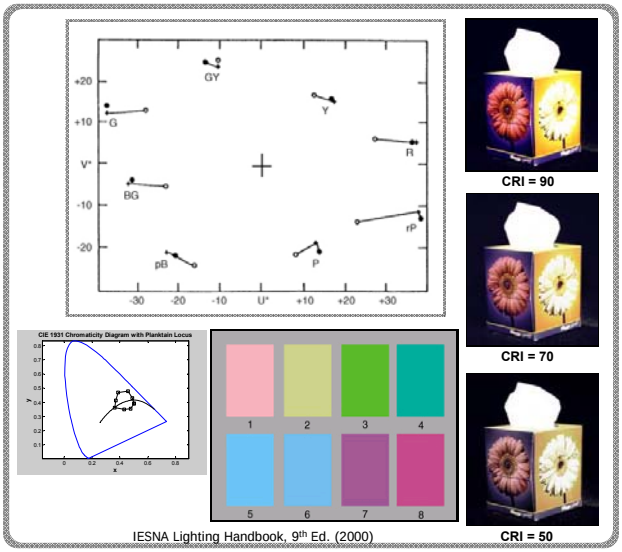
Color rendering index (CRI)

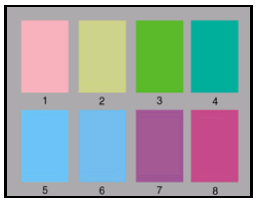
- Measure of the degree of color shift objects undergo when illuminated by the light source as compared with the color of those same objects when illuminated by a reference source of comparable color temperature.

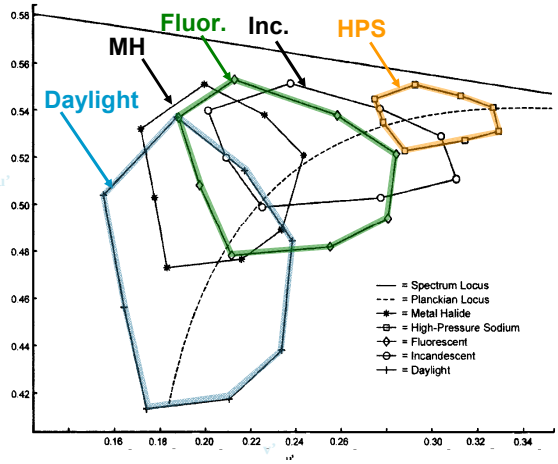


IESNA Lighting Handbook, 9th Ed. (2000)

Gamut area index (GAI)

- In general, the larger the gamut area, the more saturated the color samples are and the easier it is to discriminate between them.





Adapted from ***Human Factors in Lighting*** - **2nd Edition**
Boyce, P. R. 2003. London; New York: Taylor & Francis.